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# GEOLOGY.—*Stratigraphy and structure of Northwestern Vermont.*—I.[1]

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## GENERAL GEOGRAPHY AND GEOLOGY

The historic region described in this paper is the north end of the Appalachian Valley in the United States. This part of the Valley is called the Champlain Valley and lies partly in New York and partly in New England. In the largest view it is bounded on the east by the Green Mountains and on the west by the Adirondack Mountains, and at the south it is split by a minor group of mountains—the Taconic Range. A large part of the Valley is occupied by Lake Champlain, the surface of which is 100 feet above sea level. The bottom is below sea level. The Valley passes northward into Canada and curves northeastward, merging into the St. Lawrence Valley.

The Champlain Valley is 20 miles wide at the latitude of Burlington and extends southward for 80 miles from the Canadian border to the Taconic Range. The Valley is there divided by the Range into two parts; the western one, which is continuous into the Hudson Valley of New York, and the eastern part, which extends as the Western Valley of New England nearly to Long Island Sound. This part of the Valley also has several names for individual sections, such as Rutland Valley, in Vermont, and Stockbridge Valley, in Massachusetts. The eastern side of the Champlain Valley is sharply marked by the abrupt rise of the Green Mountain front, which trends nearly north and south and is close to the east side of the six quadrangles herein described. The western side of the Valley is also clearly marked by the bold slopes of the Adirondack Mountains in New York. Near the south end of Lake Champlain these mountains come to the shore of the Lake.

[1] Received June 6, 1932. Published with the permission of the Director, U. S. Geological Survey.

## STRATIGRAPHY

The Valley and its southern branches are floored by Paleozoic limestone, dolomite, marble, shale, and slate with a few belts of quartzite. All of these rocks except the quartzite are rather easily eroded and their surface is well worn down toward sea level. They range from Lower Cambrian age to Middle Ordovician, the older formations showing mainly in the eastern part of the Valley and the younger ones in the western part. The west half of the Valley and its extension southward into the Hudson Valley is floored mainly by a few formations of Ordovician shale and limestone, while the east half is underlain by many formations of Cambrian limestone, dolomite, marble, and quartzite. These two groups are separated by the Champlain overthrust. The latter formations also underlie nearly all of the Western Valley of New England. Thus, in a broad way, older and older rocks appear as one travels from west to east. As a result of this general progression, the eastern margin of the Valley and the front of the Green Mountains are formed by the lowest Cambrian quartzites, and by still lower formations of the Algonkian. In the heart of the Green Mountains still lower formations appear in the granites and gneisses of the Archean.

A marked departure from this plan is seen in the Taconic Range. There, the carbonate rocks which characterize the Valley disappear and nearly all the formations are of slate. One thin quartzite formation is present and one very thin limestone formation, which together form perhaps 5 per cent of the total section. There is one slate formation of Middle Ordovician age, two of Lower Ordovician age, and seven of Lower Cambrian age. No Middle or Upper Cambrian is present. The Lower Cambrian of the Taconic Range lies on or beside the Lower Cambrian of the valleys, and the two groups have no features in common except that of age. This is expressed by nature in the fact that one group makes mountains, while the other forms the valleys. Similarly, most of the Ordovician formations of the Taconic Range differ widely from the Ordovician of the surrounding valleys.

Other discrepancies of this sort are found in the Champlain Valley, so that in all one finds three major tracts in the Valley, a fourth in the Taconic Range, and a fifth in the Green Mountains, which differ strikingly from one another in the formations present and in their metamorphic condition. Each of these natural groups is called a sequence and each is separated from the others by a major fault, as shown in Fig. 1. These sequences are called Western, Central, Eastern, Taconic, and Green Mountain sequences in order to show where they are best developed. The Champlain overthrust separates the

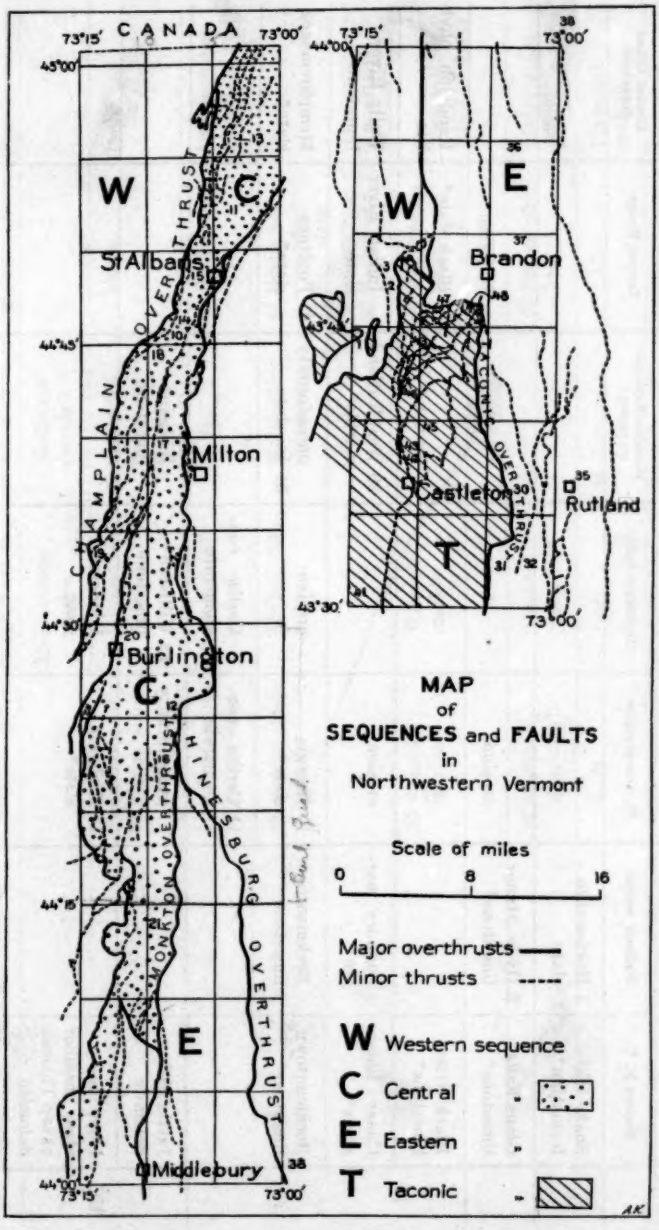


FIG. 1.—Sequences and faults in Northwestern Vermont.

TABLE 1.—Correlation Table for Champlain Valley and Northern Taconic Range. Arthur Keith, 1932

| | WESTERN SEQUENCE | | CENTRAL SEQUENCE | | EASTERN SEQUENCE | TACONIC SEQUENCE | GREEN MTS. SEQUENCE |
|---|---|---|---|---|---|---|---|
| | Eastern N. Y. | Sudbury region | St. Albans region | Burlington region | Brandon-Rutland region | Taconic Range | Central Green Mountains |
| | Snake Hill formation* | 1 Hortonville slate | | | | | |
| | Glens Falls limestone* | 2 Hyde Manor limestone* | erosion | | | erosion | |
| O | Black River limestone* | | | | erosion | Black slate* | Randolph phyllite |
| | Chazy limestone* | 3 Sudbury marble | erosion | | 30 West Rutland marble* | Indian River slate | Waits River limestone* |
| | Beekmantown limestone* | Beekmantown limestone | 10 Georgia slate* | erosion | unconformity<br>31 Ira slate | 41 Poultney slate* | Memphremagog slate* |
| | | | 11 Corliss conglomerate* | Corliss conglomerate | | | |
| UC | Little Falls dolomite | | unconformity | 12 Williston* limestone | Williston limestone | | |
| | Hoyt limestone member at top Theresa dolomite | | 13 Highgate slate* | Highgate slate | | | |
| | Potsdam sandstone | | 14 Mill River* conglomerate | | | | |
| MC | Unconformity | | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| MC | Unconformity | unconformity<br>15 St. Albans slate* | hiatus | hiatus | | |
| | | | 16 Shelburne marble | Shelburne marble | | |
| | | unconformity<br>17 Milton dolomite | Milton dolomite | 32 Clarendon Sprgs. dolomite | hiatus | fault |
| | | unconformity<br>18 Parker slate | Parker slate | | 42 Hooker slate | Ottauquechee phyllite of Perry |
| LC | | 19 Mallett dolomite* | Mallett dolomite | Wallingford dolomite* | 43 Beebe ls.* | |
| | | | | | 44 Bull slate | |
| | | | | | 45 Barker qtz. | —quartzite |
| | | 20 Winooski marble* | Winooski marble | Danby formation | 46 Hubbardton slate | Pinney Hollow schist of Perry |
| | | | | | 47 Stiles phyll. | |
| | | 21 Monkton quartzite* | Monkton quartzite* | | 48 Brezee phyllite | Albite schist |
| | | fault | fault | 35 Rutland dolomite | fault | Plymouth marble |
| | | | | Cheshire quartzite | | Cheshire quartzite |

TABLE 1.—CORRELATION TABLE FOR CHAMPLAIN VALLEY AND NORTHERN TACONIC RANGE. ARTHUR KEITH, 1932—*Concluded*

| | WESTERN SEQUENCE | | CENTRAL SEQUENCE | | EASTERN SEQUENCE | TACONIC SEQUENCE | GREEN MTS. SEQUENCE |
|---|---|---|---|---|---|---|---|
| | Eastern N. Y. | Sudbury region | St. Albans region | Burlington region | Brandon-Rutland region | Taconic Range | Central Green Mountains |
| AL | | | | | unconformity<br>36 Moosalamoo phyllite | | unconformity |
| | | | | | 37 Forestdale marble | | |
| | | | | | 38 Nickwaket graywacke | | unconformity<br>Nickwaket graywacke |
| AR | Granite and gneiss | | | | granite and gneiss | | granite and gneiss |

Fossil horizons shown by *. Formation type localities in this area are numbered and shown on map.

Western from the Central sequence; the Monkton overthrust is the boundary between the Central and Eastern sequences; and the Taconic overthrust separates the Taconic sequence from the others. There are eight principal Paleozoic formations in the Western sequence; twelve in the Central sequence; nine in the Eastern sequence; and ten in the Taconic sequence. The mutual relations of these are shown in the correlation chart (Table 1). Many of these formations can be subdivided into members, especially in the Western Sequence where fossils are numerous.

## STRUCTURE

The geologic structures of the Champlain Valley exhibit the features which are usually found in the Appalachian Valley, consisting of long, narrow folds overturned toward the northwest and split by numerous faults. Other faults (the great overthrusts) mentioned above are more than usually numerous, and bringing the extremes of sedimentation together they greatly complicate the structure of the region. The rock formations have the same north-south trend as the structures except here and there where they are shoved aside by the great overthrusts.

Because of differences between the various formations in respect to ease of erosion, the Valley is very plainly defined from the Mountains, and the weaker formations of the Valley are separated by the minor ridges of the harder formations, like the Monkton Hills. No attempt will now be made to discuss the various stages of erosion and uplift by which the surface has attained its present forms. These differ only in place but not in kind from those of other New England States. Those of Massachusetts have been described by the writer elsewhere. No space will now be given to the glacial history of the region with its tilting, erosion, and blanketing of the bed rock. Attention will be directed solely to structures in which the rocks have been changed in form, attitude, or composition, and the relation of these structures to the nature of the rocks involved will be briefly analyzed.

This region is at one of the great salients of the Appalachian system where the rocks of the earth's crust have been pushed farther forward toward the west than in adjoining regions. The axis of the salient crosses the Valley and Mountains in the St. Albans district, where the structures change trend from northerly to northeasterly. Further south—in the Rutland district—the folds have lagged behind those of the St. Albans district and even trend to the west of north. This is

the only place in the Appalachian system where such a general trend is seen. The lag is due to the massive buttress of the pre-Cambrian rocks in the Adirondack Mountains, which checked the westward advance of the folds.

The rocks of this region show the results of extreme compression and exhibit a great variety of folds, faults, and metamorphism. First came the group of great overthrusts, the Champlain being earliest, followed by the Monkton and Hinesburg thrusts, with the Taconic as a climax. Doubtless a moderate amount of folding took place at this time, but it cannot be separated from later folding. Each of these overthrusts was marked by much horizontal movement, but the Taconic overthrust was far greater than the others. Its roots lie far to the east in the Green Mountains, nearly 20 miles away. The Taconic overthrust mass was forced completely over the other thrust masses and is now to be seen overriding two of them, the Monkton and the Champlain, at the north end of the Taconic Range. On each overthrust there were brought together groups of formations of the same age but of very different nature and formed originally many miles apart.

Apparently the overthrusting reached a deadlock, being stopped by friction and piling up of the masses. The pressure was still being applied, however, and the rocks were still more folded and masked. With them were folded the overthrust planes and masses until in places they were turned upside down, as along the east side of the Taconic Range. Still further compression split many folds and formed minor thrusts and faults. Some of these, for instance the Castleton fault, would in any other region be considered large, and they were able to slice through the great overthrust masses and dislocate them into separate blocks. Such results are well seen in the vicinity of Burlington and Middlebury, where the Champlain overthrust was dislocated. A far finer example of this secondary dislocation is seen in the northern part of the Taconic Range, where a dozen secondary thrust faults have cut the overthrust mass into slices. This is by far the best exhibition of such structures yet found in the Appalachians or perhaps in North America.

The process of compression went on until in some sections—notably near St. Albans—scarcely a vestige of folding remains, all being swallowed up in a succession of slices. The planes of the great overthrusts dipped originally at low angles toward the east; they still do so in some places, though they are overturned in others. The lesser faults dip as a rule less than 45 degrees to the east.

In many places the overthrust masses were raised so high on the secondary structures that erosion has revealed the underlying rocks in fensters. The largest of these appears a few miles west of Middlebury and east of Snake Mountain, where the limestones of the Western sequence are exposed in a tract covering many square miles. This is indicated in Fig. 1. Smaller structures of the same sort are found in the vicinity of Burlington on the same overthrust which is there close to the water front. Of the same nature, but enormously greater in scale, is the structure of the region east of the Taconic Range and including the western part of the Green Mountains. All of this was brought above the erosion plane by folding and faulting subsequent to the Taconic overthrust. The outcrop of this overthrust now forms an enormous flattened Z, the middle line of which reaches from the north end of the Taconic Range into Massachusetts, where it turns back to the northeast.

A far different arrangement is seen west of the Champlain overthrust, where the Western sequence of formations prevails. Folding is at a minimum and is expressed mainly by tilting at angles which seldom are as great as 30 degrees. The tilting was mainly accomplished by normal faults which trend in a great variety of directions and of which the throw is commonly small. A very few faults of this kind are known to cross the Champlain overthrust into the region of the Central sequence. It is possible that more will be found but probably not many. The rocks of this sequence exhibit practically no metamorphism except some slaty cleavage near the Champlain overthrust, and the whole system of structures differs so widely from those on the east side of the Champlain fault that they obviously belong in different provinces.

Hand in hand with the movements of folding and faulting there was deformation by metamorphism. This was least in the Western sequence so that shales were barely transformed into slates and fossils were scarcely deformed. At the east, however, the changes were extreme; no rocks escaped entirely and some were mashed almost beyond recognition. Granites were mashed to schists in places, and interbedded quartzites and shales were dissected until they resemble augen gneiss. Interbedded limestones and dolomites were transformed into strings of blocks of ruptured dolomite, between which was forced calcite marble. Such metamorphism was accomplished not only by physical rupture and separation but by chemical recrystallization. The details of this differ widely between marbles, slates, quartzites, graywackes, and granites. The differences in aspect produced by these chemical changes are greatest in rocks which originally

contained alumina in the form of clay or feldspar. In such rocks the development of micas proceeded to great lengths, so that new structure planes—schistosity—were produced in them, and rocks of different original composition approach each other closely in appearance. In these rocks lithologic composition is of little value in fixing their ages, and phyllites of Ordovician and Algonkian ages may be identical in appearance.

Between the extremes of metamorphism there are many intermediate grades. The western margin of readily noticeable metamorphism is not far west of the Taconic overthrust at the south, and of the Champlain overthrust at the north. The metamorphism is substantially limited to the region covered by overthrusts and doubtless is due to the combination of intense lateral pressure with the greatly added overburden of the overthrust mass. It is because of this intense recrystallization of the limestone and dolomite, and the changes of bulk, color, and pattern that went with it, that this region has the largest body of fine marble in the United States.

## INDIVIDUAL FORMATIONS

The general character of the formations exhibited in this region has been mentioned briefly in the foregoing general descriptions. The formations are described according to sequences, all of the formations in one sequence being treated before considering those of another sequence. Each of the sequences, and of the formations contained therein, is shown in the correlation table. The first sequence described is the western one and the others are described in the order from north to south. On the map and in the correlation table numbers show all of the formation type localities that are in this region.

The outcrops of rock are very good in some parts of the district, such as the northern part of the Taconic Range and the upper slopes of the hills and ridges throughout the region. All of the ledges have been scraped and polished by the Pleistocene glaciers, and the decomposed rock has almost everywhere been removed. On the other hand, exposures are very poor in the low ground, most of them being covered by glacial drift. The lower levels of the Valley are usually filled with glacial clay deposited in the glacial lakes at various stages. This clay conceals everything for great areas near Lake Champlain. In the eastern and higher tracts there are numerous sand plains and terraces ranging from 200 to 1,600 feet in altitude. These are particularly clustered around the points where the rivers come out of the mountains, and they cover all kinds of the bed rock, so that in places it is

impossible to tell precisely how the formations connect from side to side of a delta. In the Green Mountains boulder clay conceals most of the rock, which only here and there projects through it or is uncovered by the down-cutting streams. On one kind of glacial deposit or another it is possible to travel many miles continuously without any rock exposures whatever. This drift blanket is most oppressive in the country near and north of St. Albans, where stratigraphic changes are numerous and thrust faults are very common. In tracing the formations, however, much help is obtained from the characteristic topography of each formation.

### WESTERN SEQUENCE

The sedimentary rocks of this sequence begin with the Upper Cambrian and rest directly upon the Archean granite and gneiss. A detailed description of these formations is not given here because the writer's field work has been mainly directed to the highly disturbed rocks of the other sequences. Some knowledge of them is needed, however, as a setting for the geology east of the Champlain overthrust.

The first Paleozoic deposit of this sequence is the Potsdam sandstone. This is found in many belts around the Adirondack Mountains and usually makes prominent ridges or mountains. On the east side of the Adirondacks this formation is a quartzite with a basal conglomerate and closely resembles the Lower Cambrian Cheshire quartzite of the Eastern sequence.

The Potsdam is believed to be of Upper Cambrian age but has so far yielded no fossils. There is a zone of interbedded quartzite and dolomite between the Potsdam and the overlying Theresa dolomite of Upper Cambrian age, which is in favor of an Upper Cambrian age for the Potsdam beds. The Potsdam is included in Ulrich's Ozarkian system, together with the Theresa and Little Falls dolomites.

The Theresa dolomite is a gray massive dolomite with many interbedded layers of sandstone, particularly at the base as already noted. The formation contains trilobites which establish its age. Above the dolomite, but included with the formation as a member, is the Hoyt limestone. This also contains beds of gray dolomite and oolite, and numerous fossils.

The Little Falls dolomite is similar to the Theresa dolomite in lithologic appearance and also has very few fossils. Nodules of black chert are found in this dolomite and also a remarkable development of cryptozoon reefs.

The first beds of the Ordovician are those of the Beekmantown limestone. All of the divisions of the Beekmantown are found in the

towns of Orwell and Shoreham, immediately northwest of the end of the Taconic Range. The formation consists chiefly of limestone with numerous beds of dolomite. Fossils are very numerous in some parts of the formation, and there are many peculiarities in the lithology in the limestone layers. Most of the limestones have a bluish color whereas the dolomites are light or dark gray. Some of these beds are seen along the Champlain overthrust west and northwest of St. Albans.

The Chazy limestone, which follows the Beekmantown, is also composed mainly of bluish limestone and fine gray dolomite. The dolomite also has lighter colored layers and some which weather with peculiar chamois-colored surfaces. The formation carries many fossils which serve to distinguish it from the Beekmantown. There is some uncertainty about the age of some dove-colored limestones which have been assigned both to the Chazy and to the Beekmantown.

The Sudbury marble, which outcrops in the town of Sudbury at the northwest end of the Taconic Range, appears to be of Chazy age, although it has no fossils. It rests upon the Beekmantown and it underlies limestone of Trenton age, being only separated from the latter by a heavy bed of gray dolomite. The marble is, for the most part, snow white but contains also a few cream colored beds of fine dolomite. It is possible that these three formations belong in the Central sequence instead of the Western, but this is still in doubt on account of the prevalence of thrust faults in that district.

The Trenton, which normally follows the Black River, is best developed in Western New York. In the Schuylerville region of New York, which joins this region on the southwest, the Trenton is possibly represented by the upper part of the Normanskill shale which includes at the top the Ryesdorph conglomerate member, and also by the Snake Hill formation. The greater part of the Normanskill shale is regarded as of Chazy age. All of these shales are gray or dark, with interbedded layers of sandstone and cherty slate, and contain fossils, chiefly graptolites.

The Hyde Manor limestone, occurring near the north end of the Taconic Range, contains a good brachiopod fauna of Trenton age, entirely different in aspect from that of the shales of the same age at the west and southwest. This limestone has a decided blue color and consists of massive beds interlayered with thin slabby strata. Considerable schistosity is evident in this limestone and it is strongly folded, which facts support an assignment of the formation to the Central sequence. Fossils are rather common, however, which tends in an opposite direction toward the Western sequence.

Lying above the Hyde Manor limestone is the Hortonville slate, a dark or black slate with portions which are sufficiently altered to be called phyllite. There are also in the slate a few small seams of siliceous material giving a local banded appearance. As a rule the bedding is obscured by the cleavage. This is well exposed around Hortonville, Vt., and, though unfossiliferous, is correlated with the Snake Hill formation of New York.

### CENTRAL SEQUENCE

The Central sequence is exhibited in two general areas, as shown on the correlation chart. The lower half of the column is the same for each area, but the upper half differs materially. Some differences are due to unconformity and overlap which produced Middle and Upper Cambrian beds found only in the St. Albans region. Also, in the St. Albans region there are two Ordovician formations which doubtless have been eroded from the Burlington region, owing to the greater depth of erosion there. The section passes from a quartzite at the base through dolomites and marbles and into slates at the top.

*Monkton quartzite.*—The sequence begins with the Monkton quartzite, of Lower Cambrian age. This is seen in Burlington in quarries and natural exposures, and is one of the best key rocks of the region. The original thickness of this formation is not known nor what beds might precede it, because the base is cut off on the Champlain overthrust. The formation appears on several faults and folds in the township of Monkton, 17 miles nearly south of Burlington, from which the formation is named, but in no place is anything lower than the Monkton exposed. In that town the Lower Cambrian Cheshire quartzite is brought in contact with the Monkton on the Monkton overthrust, which there separates the Central and Eastern sequences.

The Monkton consists very largely of a dense, fine-grained quartzite whose notable feature is its strong color. Red colors prevail, including all shades from brick red, brown, and buff, with a few beds of pure white quartzite. None of these beds is traceable for any considerable distance. The top of the formation has interbedded layers of a tough, fine dolomitic marble, also rather highly colored with red or pink. These beds are of the same composition as those of the overlying Winooski marble and make a transition between the two formations. A few Lower Cambrian fossils have been found in the uppermost layers of the Monkton but are rarely to be seen until the thin slabs of quartzite have been exposed to the weather for a considerable period, thus leaching out a calcareous cement and permitting the interior structures

to be exposed. Cross-bedding, ripple marks, and trails of animals are numerous in the formation, showing that it was produced in shallow waters.

The Monkton quartzite is eroded very slowly so that it forms mountains or high hills, by which its course may be readily traced. It is considerably dissected by faults, so that the quartzite forms few continuous ridges but rather a lot of irregular, elevated tracts. This relation is very well seen around Mt. Philo in Charlotte, 14 miles south of Burlington. The most notable of the Monkton quartzite mountains is Snake Mountain, 6 miles northwest of Middlebury, which is a remnant of the Champlain overthrust plate, lying on Ordovician shale. West of this lie the low limestones and shales of the Western sequence, while east of it are other limestones of the same sequence, appearing through a great fenster in the overthrust. The rigidity of this formation and its ability to carry on the overthrust plate is well exhibited in this region.

*Winooski marble.*—This formation consists of very massive, tough, and thick-bedded dolomite with the basal passage beds already mentioned. The formation is marked by the strong reds, browns, and pinks like those seen in the Monkton. Some layers have these colors strongly mottled with buff or white in very irregular patterns and have long been used for ornamental marble. The original quarry was on the north bank of Winooski River at Burlington, and the principal quarries are in Swanton, six miles northerly from St. Albans. The mottled marble there abuts against the Champlain overthrust and forms a striking contrast with the light marbles of the Chazy and Beekmantown on the other side of the fault. The beds of the Winooski marble resist erosion very strongly and outcrop freely, thus furnishing a fine key rock. There is some interbedding between the Winooski marble and the overlying gray dolomite of the Mallett. A minor peculiarity of the Winooski is the series of very thin siliceous seams which project in wavy lines from the surface of the massive dolomite. Fossils are extremely rare in this marble but a few have been found. The strongly mottled beds seem at first glance to be fossiliferous, but probably are not.

*Mallett dolomite.*—This dolomite is exposed in the bluffs around Mallett Bay northwest of Burlington. Excepting the few basal passage beds the formation consists mainly of massive light or dark gray dolomite. With this are interbedded seams and layers of dolomitic sandstone which in the northern part of the region expand to form quartzite beds as much as 10 feet thick. These are most prominent

north of St. Albans, and their white reefs stand in relief above the dark gray dolomite. This is very striking near the Canadian boundary where the quartzite beds are cut off one after another against the Champlain overthrust. A few fossils of Lower Cambrian age have been found in this formation, mostly in slabby layers in its upper part. The dolomite resists erosion, especially in its quartzite beds, and makes considerable ridges separated by drift-filled valleys.

*Parker slate.*—This formation is named from its excellent exposures around the sides of the Parker Cobble and on the old Parker farm. It there contains large numbers of Lower Cambrian fossils and is the celebrated locality from which Walcott was able to make his first analysis of the Taconic system of Emmons and demonstrate the existence of beds older than the Upper Cambrian. It has long been the most important Cambrian formation of the region. This formation is the same as that previously called "Colchester" by the present author and is renamed because of the poor exposure of the formation in Colchester and, indeed, anywhere south of Parker Cobble. A full section of the formation is exposed at Parker Cobble together with the overlying and underlying formations.

The formation consists mainly of slaty shale which is dark gray or slightly color banded and which contains considerable original mica. This mica permits the layers to be split readily and the fossils to be uncovered. There are also in the formation a few sandy layers and some lenses a few feet thick of a gray dolomite which weather with a prominent brick-red surface. A notable feature in the slate appears about seven miles north of St. Albans in the form of massive, blunt lenses of blue limestone surrounded by the slate. These have the same form and relations as the limestone reefs of the Upper Cambrian Highgate slate.

The formation represents a sharp change in lithology from the preceding dolomites, and no interbedding has been noted. The top of the formation, however, is marked by a decided unconformity, by which the formation is reduced to almost nothing from a maximum thickness of perhaps 100 feet. The unconformable contact of the overlying Milton dolomite upon the Parker slate is well exposed a few yards north of the highway from St. Albans to St. Albans Bay, and also about one-half mile south of the same highway. At the locality north of the highway the Milton consists of dolomite conglomerate containing large boulders of dolomite and slabs and pebbles of the fossiliferous Parker slate. The fossils both in the pebbles and in the matrix were determined by Schuchert to be of Lower Cambrian age. South

of the latitude of Burlington there are no known exposures of this formation. There are numerous localities, however, where it may be present but concealed by glacial drift.

The slate is a weak formation and is only rarely exposed at the valley margins. A good exposure of this is seen in a pit for road material about one mile northwest of Highgate Center, where some 20 feet of slate containing Lower Cambrian fossils are exposed. Above the slate and forming the crest of the hill on the east lies the Milton dolomite, there consisting mainly of dolomite conglomerate. Between the two formations there is a distinct unconformity, on which beds of both formations are cut out. North and northeast from this locality at scattered points in the minor valleys there are other outcrops of slate, probably Parker.

*Milton dolomite.*—The Milton as here defined is characteristically a dolomite, but it is one of the most variable formations in this region. It varies in thickness from perhaps 700 feet down to 8 or 10 feet, and it varies in character from massive gray dolomite, fine and coarse-grained, thick bedded and slabby, through sandy dolomites and quartzites to a coarse dolomite conglomerate. In the upper part of the formation, and only where it is thick, considerable black chert is found in the dolomite.

The rocks just mentioned are those which are usually seen in the Milton, but there is an apparent component of the formation which is very rarely visible, i.e., a series of slate layers interbedded with the other rocks. They have thus far been found in full only in the section below Highgate Falls. At extreme low stages of the River a considerable section is exposed which is not ordinarily visible and in this are found numerous layers of slate. These slates have the same characteristics as the Parker slate, but a few fossils were found in them, which are stated by Schuchert to be of Upper Cambrian age, thus classing them with the Mill River conglomerate. Numerous minor unconformities were brought out between the slates and the conglomerates and sandstones of the Milton, which emphasizes clearly their torrential nature. This general conglomeratic nature is also characteristic of the Milton as here defined in practically all of this area and is most prominent from the latitude of Milton northward to Canada. In some places these dolomite conglomerates consist of angular fragments of all the kinds of rock which appear as layers in the formation, and thus may be properly classified as intraformational. The coarse basal conglomerates, however, which carry boulders 3 or 4 feet in diameter, and many rounded fragments of dolomite as well as slabs of Parker slate, are not intraformational.

In the original definition of the Milton by the writer the formation included at the top about 80 feet of conglomerates, some of them dolomite conglomerates and others largely of limestone, with a few feet of very fossiliferous limestone containing many Upper Cambrian fossils. The general conglomeratic habit of these upper beds was the same as that of the beds below, and for lack of decisive evidence the lower part of the formation was also included in the Upper Cambrian. Since that time Middle Cambrian fossils have been discovered by Howell in the St. Albans region in the St. Albans slate, which underlies the Mill River conglomerate and Highgate slate and overlies the Milton dolomite. Since the discovery of the Middle Cambrian formation the author has mapped the region in detail and has continued the tracing of the Middle Cambrian beds, so that the position of much of the original Milton beneath the Middle Cambrian is assured. The upper part of the original Milton seems clearly of Upper Cambrian age, and it is excluded from the Milton as here defined, and is named Mill River conglomerate.

*Shelburne marble.*—This formation consists almost wholly of white marble of fine and medium grain with a few layers of light colored dolomite. The formation is exposed for only a few miles north of the latitude of Burlington, being there faulted out and eroded. Southeast of Burlington, and particularly in the township of Shelburne, from which it is named, the formation becomes prominent and occupies several parallel belts. From this point southward the marble is almost continuous and is only interrupted for short distances by changes in the folds. It is represented in the Eastern sequence by a marble formation of the same character which is almost continuous through the quarry region of Middlebury, Brandon, Proctor, and Danby. In all these places the marble is overlain by the Williston limestone, but between them there is a very important unconformity. In the St. Albans region between the horizons of the Shelburne and the Williston there appear the St. Albans slate, the Mill River conglomerate, and the Highgate slate. The basal contact of the Shelburne with the Milton dolomite is very seldom seen, but apparently there is a transition between them.

The Shelburne marble contains no fossils so far as is known, but it is uniform and is a regular unit in the Lower Cambrian succession of the eastern part of the Valley. It also occupies the same position in the Lower Cambrian Eastern sequence. Assignment of the Shelburne to the Lower Cambrian is also supported by the presence of white marble boulders in the conglomerates of the Upper Cambrian in most of their exposures.

*St. Albans slate.*—Middle Cambrian fossils were found in this formation by Howell at the west border of the city of St. Albans, after a thorough search which was prompted by the statement in the literature that Middle Cambrian fossils had been found in St. Albans. By careful work Howell discovered several other localities for the Middle Cambrian and also for Upper Cambrian fossils in the overlying Highgate slate. These beds have been traced by the writer into the western part of the township of Milton. Apparently they are cut out a few miles south of Highgate Center between the Milton dolomite and the Highgate slate. There is, however, a fair prospect that they can be identified in one of the beds of slate which is exposed only at low water below Highgate Falls. The formation contains only slate, which is dark gray and locally banded, and is micaceous like the Parker slate.

*Mill River conglomerate.*—This formation is one of the most interesting in this region, although it is one of the smallest. It is seen at St. Albans resting on the Middle Cambrian slate, and also in fine exposures at Missisquoi River just below the falls at Highgate Center, 9 miles nearly north of St. Albans. The formation is of Upper Cambrian age, and an abundant fauna is secured from some of its limestone layers. The fossiliferous beds form slabs an inch or two thick which are very characteristic, and their fragments appear as angular slabs in the later conglomerates. When the beds were first described by the writer they were included in the Milton dolomite because each formation was notably conglomeratic and because no fossils were known in the lower part of the Milton. The later discovery of the Middle Cambrian slate compelled the separation of these two formations, and the name "Missisquoi" was given to the conglomerate as the only name that seemed available. Unfortunately, it had been used in another sense for several Cambrian formations east of the Green Mountains and thus should not be used here. The name Mill River had already been selected by Howell and the writer for a conglomerate three miles southwest of St. Albans, which was later shown by the writer's detailed tracing to be the same formation. At the Mill River section the Middle and Upper Cambrian beds are exposed and contain fossils.

This formation is characteristically a conglomerate, and the fossiliferous limestones are only a small part of the formation. All of the conglomerate beds contain angular fragments of dolomite, sandstone, and quartzite, such as are found in the older Milton dolomite. Several layers also contain fragments and boulders of blue limestone and white

marble, many of which exceed 3 feet in diameter. The marble appears to have been derived from the Shelburne marble, which is the only rock of the sort which can be older than Upper Cambrian. The blue limestone boulders resemble some of the limestones of the Ordovician, but they resemble equally well the blue limestones found in the reef deposits of the Lower Cambrian Parker slate, found a few miles southwest of Highgate Center. In the original description of the conglomerates by the writer it was noted that they strongly resemble tillites. No scratched pebbles have been found in the formation, however, and that question must remain in abeyance.

The conglomerate outcrops freely and forms low ridges, but it is doubtless covered in many regions by the glacial drift. Many good sections, however, fail to show the conglomerate, so that it is not continuous throughout the region. This conglomerate bears a very strong resemblance to the Lower Ordovician Corliss conglomerate, which is quite natural in view of the derivation of the boulders from the same sources. The Corliss, however, contains pebbles of uppermost Cambrian ("Saratogan") age. The difficulty of separating the two is most considerable for a few miles from Highgate Falls south to Skeels Corners, for the Mill River conglomerate together with a part of the Milton dolomite is repeated by a thrust fault and now lies on top of the Highgate slate. The thrust fault is well exposed in the gorge at Highgate Falls. Similarly fine exposures of the formation are seen from one to two miles west of Georgia Center, resting on the Milton dolomite.

*Highgate slate.*—This slate rests upon the Mill River conglomerate in the gorge at Highgate Falls, and is named from that locality. Most of the formation is exposed between the conglomerate and the thrust fault above mentioned, and consists in the main of dark gray or black slate, usually well banded and with pronounced cleavage. Some layers might properly be called phyllite. The banding is so regular that its resemblance to glacial varves has already been noted and the glacial origin of the slate discussed in connection with the underlying conglomerates. In addition to the usual banded slate several beds of dolomite a foot or so thick are found in the lower part of the slate. These are tightly folded and in places torn apart, thus giving a better idea of the great deformation of these rocks than is obtained from the slates. In the upper part of the section in the gorge there are numerous sandy seams from 1 to 2 feet thick which appear in the slate a few miles to the south. The highest part of the slate comes in about one-half mile to the north of the gorge in the outskirts of Highgate Center.

There and at numerous localities up to the Canadian border the slate is interbedded with thin layers of blue limestone and gray dolomitic limestone. These give a strongly striped appearance and in a good-sized ledge are plainly visible at a distance. Strong folding has magnified the apparent size of the formation, which seems to be 500–600 feet thick.

A remarkable phenomenon in the Highgate slate is the development in many localities of large masses of limestone entirely surrounded by the slate. They occur usually in the upper part of the formation above the horizon of limestone layers above mentioned. They are found from Canada southward nearly to Burlington. They resist erosion more than the surrounding slates and hence form prominent points in the landscape, resembling gigantic turtles. The maximum size so far found is about 200 feet long and 80 feet wide, and they project from 10 to 20 feet above the general level. Numerous contacts with the slate have been found and the ends of the limestone bodies are very blunt and rounded so that they give the effect of having pushed aside the slates during their growth. The slates pass above and beneath the margins of the limestone bodies and can be seen completely surrounding the small bodies. They occur in clusters as well as individually, a relation which is very well seen about two miles northwest of Georgia Center.

These limestone bodies are, for the most part, made up of massive, dense blue limestone without any visible structure. In the large masses, however, there is apt to be a portion of the mass showing a subdivision of the blue limestone into roughly rounded bodies separated by narrow zones of brownish impure limestone and also a secondary quartz partly filling the spaces between the limestones. These rounded areas of blue limestone are the cross sections of columns which stand nearly vertical and can be seen in solution cavities to extend down at least 5 feet from the surface. The most notable example is 2 miles west of north from Georgia. It is evident from these exposures that the structure of these limestones is not due to any sedimentary process, but is the result of some reef-building organism. Some of these reefs appear to have persisted to the end of the Highgate deposition, for they are directly overlain in places by the Corliss conglomerate, and appear to have furnished much local material for the conglomerate. A good example is also seen 2 miles nearly west of Georgia Center.

Upper Cambrian fossils were found by Walcott in this formation, and others were found by the writer in thin limestone seams in High-

gate Center. The latter were decided by Walcott to be of Upper Cambrian age. The formation runs in a continuous belt from the Canadian border to the latitude of Burlington, where it is cut off by the Hinesburg overthrust. There is no known contact between the Highgate and the next younger formation, the Williston limestone. The two lap past each other for a few miles east of Burlington but they appear in different folds, so that the exact nature of the contact is undetermined. In and south of that tract, however, the Williston rests upon the Lower Cambrian Shelburne marble, and the Highgate, Mill River, and St. Albans formations are absent. Since these formations represent the Middle and Upper Cambrian, there is a great hiatus between the Williston and Shelburne formations.

*Williston limestone.*—This formation is named from its exposures in the western part of the township of Williston about 5 miles southeast of Burlington. It is cut off at the north in Milton by faulting and erosion but extends southward to the limits of the Central sequence. It also appears in the eastern sequence and forms a practically continuous belt in the western part of that sequence southward through Vermont. It contains fossils in its outcrops in Williston and South Burlington, and also about a mile west of Brandon in the Central sequence which were pronounced by Schuchert to be of Upper Cambrian ("Saratogan") age.

The formation consists of a thick series of beds of hard gray dolomite and of blue limestone largely altered to marble. The beds are from a few inches to a few feet thick and are greatly disturbed. The hard dolomite layers are folded and broken apart into segments, and the marbles are mashed and squeezed into the gaps and spaces between the dolomite bodies. It is only in the few layers of dolomite and limestone which are least disturbed that the fossils are found. The Williston is an important formation but its thickness can only be estimated roughly on account of the great deformation which it has suffered. It covers broad areas, however, and is doubtless as much as 500 or 600 feet thick. The contact of the limestone with the Shelburne marble is a sharp one and the change in sedimentation is very marked. Probably half of the Williston consists of dolomite, while the Shelburne marble has very little. The repeated change from dolomitic to calcareous beds in the Williston is in great contrast with the even deposition in the Shelburne.

*Corliss conglomerate.*—This conglomerate, like the Mill River conglomerate, is one of the striking and important formations of this region. It rests upon the Highgate slate and forms a series of lenticu-

lar deposits between the Highgate and overlying Georgia slate, at intervals from Canada to their end, five miles south of St. Albans. There is little difference in appearance between these two conglomerate formations, but their stratigraphic associations differ widely. The Mill River contains Upper Cambrian fossils and fossiliferous pebbles of the Lower and Upper Cambrian. The Corliss contains the same Cambrian pebbles, and also some of "Saratogan" age which were found at the Corliss Ledge, 5 miles northeast of St. Albans. These "Saratogan" forms show the Corliss to be post-Upper Cambrian, as they are the same as fossils found in the Williston limestone. The conglomerate is overlain by the Georgia slate, which contains fossils immediately above the contact and at a still higher horizon. The "Saratogan" fossils of the Williston limestone and its pebbles in the Corliss conglomerate were determined by Schuchert. He also made a preliminary assignment of the Georgia slate to the post-Beekmantown part of the Ordovician. On further consideration he now considers the Georgia slate to be of Beekmantown age. This automatically assigns the Corliss conglomerate to the early part of the Beekmantown.

The Corliss conglomerate consists in the main of pebbles and boulders of various limestones, marbles, and dolomites, most of them being limestone. The thin slabs of fossiliferous Upper Cambrian limestone derived from the Mill River conglomerate are numerous and conspicuous. Fossiliferous pebbles of Lower Cambrian limestone are occasionally found, and one boulder of blue limestone with apparent cryptozoa lies in the conglomerate at Marye ledge two miles south of St. Albans. A limestone boulder 60 feet long and about 30 feet wide was found in the conglomerate 4 miles north of St. Albans. In the same exposures there were many boulders up to 5 or 6 feet in diameter. In the original description of this region by the writer the very strong resemblance of the Mill River and Corliss conglomerates led to their description as one formation—the "Swanton conglomerate." Later detailed mapping and study showed that there were two conglomerates and that the Mill River—the older one—was placed by thrust faulting south of Highgate Center in the position of the Corliss on top of the Highgate slate, thus causing the confusion of the two.

*Georgia slate.*—This formation is the youngest known in the sequence and outcrops continuously from the Canadian border to the northern part of the township of Georgia, 6 miles southerly from St. Albans. The formation consists almost wholly of slate of a dark gray color and is fine-grained. It is strongly cleaved and usually not well banded, and the structure and thickness of the slate can only here and there

be determined. The formation occupies an area which widens to 3 miles at the Canadian boundary. It is probably 1,000 feet or more in thickness. A very few limestone beds are found in this slate and in one of them, 4 miles northeast of Highgate Center, were found the fossils of Beekmantown age already mentioned. The bottom layers also contain fossils of the same age, near the Canadian border.

The only change from the usual type of slate in the Georgia appears in its northeastern portions where there are massive and thick bedded layers occasionally sandy in texture. These have a whitish color on the weathered surfaces. Most of the slates are very similar to those of the Highgate and the two can scarcely be separated without fossils. Where the Highgate contains numerous limestone beds or the limestone reefs the two formations can be distinguished. Wherever the Corliss conglomerate is found it furnishes a satisfactory means of drawing the boundary of the Georgia slate. In the wider northern areas of the slate there are found here and there ledges of the conglomerate, some of them of considerable size. The structural relations of the slate to these conglomerates can not now be determined.

*(To be concluded)*

BOTANY.—*New Central American Asteraceae collected by H. H. Bartlett.*[1] S. F. BLAKE, Bureau of Plant Industry.

Study of the specimens of Asteraceae (except Eupatorieae) collected by Prof. H. H. Bartlett in British Honduras and Guatemala during the 1931 expedition of the Carnegie Institution and the University of Michigan has brought to light three new species, as well as a new genus represented by a plant long ago described by Bentham as an *Oliganthes*. These are described below, and with them a new *Aplopappus* collected in Tamaulipas by Prof. Bartlett in 1930.

**Harleya** Blake, gen. nov.

Capitula homogama tubuliflora. Involucri oblongo-turbinati phyllaria multiseriata gradata sicca cuspidato-acuminata erecta. Receptaculum parvum nudum planiusculum leviter alveolatum. Corollae regulares aequales, tubo cum faucibus infundibuliformi, limbo 5-fido. Antherae base alte sagittatae, auriculis obtusis ecaudatis. Styli rami subulati hirtelli. Achenia turbinata 4–5-costato-angulata saepius costis 1–5 minoribus praedita inter costas glandulari-papillosa. Pappus coroniformis cartilagineus crassus obscure crenatus.—Herba perennis subsimplex bipedalis stolonifera, foliis alternis petiolatis ovalibus vel rhombico-ovalibus penninerviis repando-

[1] Received May 20, 1932. Based (in part) upon collections made by an expedition of the Herbarium and the Museum of Zoology of the University of Michigan collaborating with the Department of Historical Research of the Carnegie Institution of Washington in a biological survey of the Maya area.

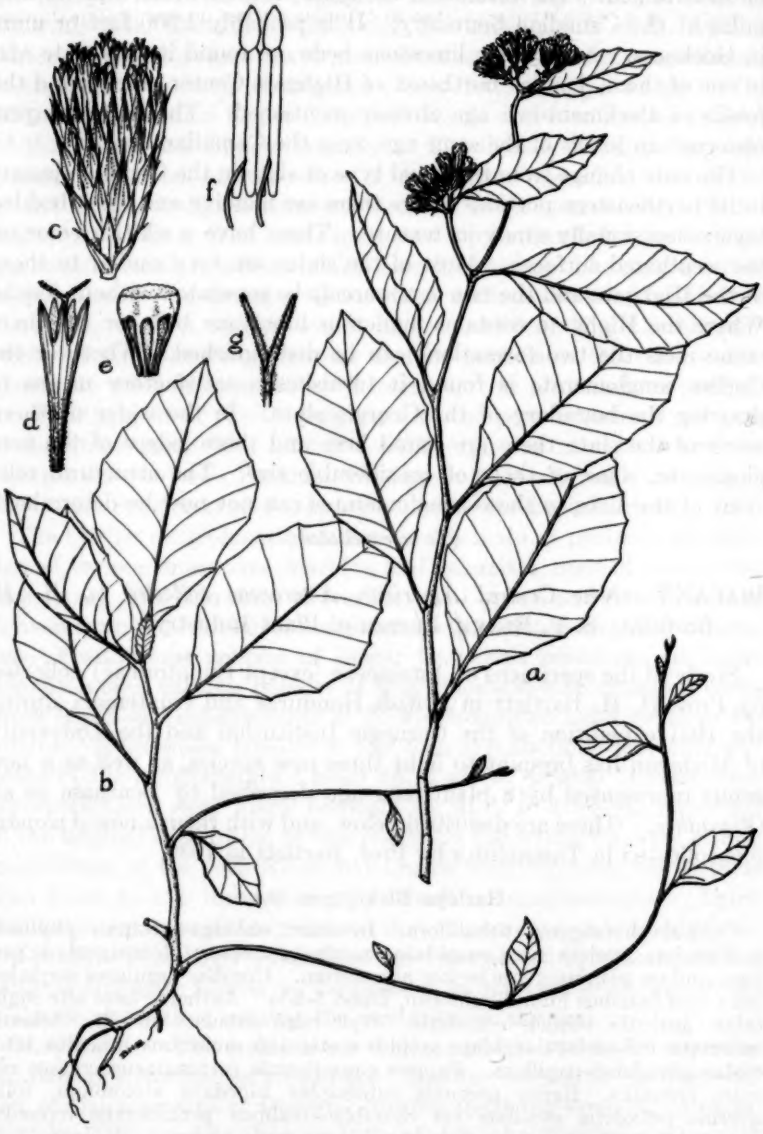


**Fig. 1.**—*Harleya oxylepis* (Benth.) Blake.—*a*, upper part of plant, × 1/2; *b*, plant with runners, × 1/2; *c*, head, × 3; *d*, corolla, × 3.5; *e*, achene, × 9; *f*, stamens, × 9; *g*, style branches, × 6. Fig. *b* from *Bartlett* 13142; other figures from *Bartlett* 12042.

denticulatis supra glabris subtus dense albido-tomentosis, capitulis mediocribus parvis 8–9-floris subsessilibus in cymulas parvas densas brevipedunculatas terminales et e axillis supremis orientes aggregatis, corollis purpureis. Species typica *Oliganthes oyxlepis* Benth.

**Harleya oxylepis** (Benth.) Blake.

*Oliganthes oxylepis* Benth.; Benth. & Hook. Gen. Pl. **2**: 233. 1873; Blake in Standl. Contr. U. S. Nat. Herb. **23**: 1418. 1926.

YUCATAN (or Tabasco): *E. P. Johnson* 21 (type coll.: photog. and fragm. in U. S. Nat Herb., ex herb. N. Y. Bot. Gard.).

BRITISH HONDURAS: Cocquericot, El Cayo District, 16 March 1931, *Bartlett* 12042; Tea Kettle, El Cayo District, 12 May 1931, *Bartlett* 13142.—The habitat is given as follows: Alluvial soil on river banks, several feet above water but subject to occasional overflow, only flowering, apparently, if in good light (Bartlett in litt.).

This interesting plant was briefly diagnosed by Bentham in 1873, in his discussion of *Oliganthes* in the Genera Plantarum, in the following words: ". . . in altera (*O. oxylepide*, Benth.) ex Yucatan Americae centralis E. P. Johnson n. 21, capitula 8-flora, pappo plane nullo, folia in hac dentata, in caeteris integerrima." Dr. H. A. Gleason, in his first revision[2] of the North American Vernonieae, retained it in *Oliganthes*, with the statement that he had seen no specimens, but in his treatment of the tribe in the North American Flora (**33**: 102. 1922) excluded it without otherwise accounting for it. Some years later, having found a sheet of the type collection among some specimens sent me for study from the New York Botanical Garden, I presented a description in Standley's "Trees and shrubs of Mexico." The excellent specimens collected for Dr. Bartlett agree perfectly with the original collection and show that the species can not be retained in *Oliganthes*, but must be made the type of a new genus most closely related to *Struchium* (*Sparganophorus*).

The genus *Oliganthes*, which has received several synonyms, was originally described by Cassini (1817 and 1818) and based on a plant (*O. triflora* Cass.) said to have been collected in Madagascar by Commerson. Recent authors have considered the original habitat erroneous, and in both Bentham and Hooker's Genera Plantarum and O. Hoffmann's treatment of the family in Engler & Prantl's Natürlichen Pflanzenfamilien the genus is reported from America only. Humbert, however, in his study of the Compositae of Madagascar, mentions not only the original specimen of Commerson but also recent collections by Perrier de la Bathie and Scott Elliot. No specimens of the Madagascar plant are available to the writer, and it seems necessary for the present to follow the course of all recent authors and consider the Madagascar species congeneric with the American species currently referred to the genus. A recent study of these, and of the very closely related and perhaps not satisfactorily separable current genera *Piptocoma* Cass. and *Ekmania* Gleason, has shown that *Oliganthes oxylepis* Benth. can not be

[2] Bull. N. Y. Bot. Gard. **4**: 235. 1906.

retained in *Oliganthes*. All the true species of *Oliganthes* are shrubs or trees, with small or very small heads aggregated in dense terminal corymbiform panicles. Their pappus is typically double, the outer of numerous usually persistent squamellae, free or united into a crown, the inner of 2–13 deciduous often twisted linear paleae; sometimes simple, of squamellae only, these free and very small or larger and united into a lacerate crown; in one species (*O. condensata*) the pappus is sometimes wanting (?). The species of *Piptocoma* and *Ekmania* are also woody, with somewhat larger and more loosely arranged heads, but with similar pappus.

*Oliganthes oxylepis*, as contrasted with the true species of the genus, is a low perennial herb bearing leafy stolons from the lower or sometimes even from the uppermost axils. The heads are larger and very much less numerous, and the involucre is composed of very numerous cuspidate-acuminate phyllaries. The short, thick, somewhat turbinate achene is unequally and subalately 4–5-angled and usually with 1–5 weaker ribs, and obscurely glandular-papillose between the ribs; the thickened, cartilaginous, obscurely crenulate, annular pappus is 0.3–0.5 mm. high and about a third to a quarter as long as the achene. Its herbaceous habit and cartilaginous annular pappus remove the species very definitely from the *Oliganthes* group and place it next to *Struchium* P. Br. (*Sparganophorus* Gaertn.), a monotypic genus of tropical America and Africa. In that genus the tiny corollas are only 3–4-toothed, the achenes 3–4-angulate-ribbed, and the anther bases acuminate. It is consequently necessary to place *O. oxylepis* in a new genus, which I have much pleasure in naming *Harleya* in honor of Prof. Harley Harris Bartlett, whose labors in various fields of American and foreign botany have been numerous and fruitful.

**Aplopappus bartlettii** Blake, sp. nov.

Herba perennis pedalis dense glandulari-pubescens et patenti-pilosa, rhizomate tenui repente; caules suberecti paullum ramosi dense foliosi; folia uniformia spathulata sessilia subintegra ca. 3 cm. longa 8 mm. lata obtusa 1-nervia utrinque viridia; capitula longe pedunculata mediocria flava radiata solitaria terminalia et in axillis superioribus; involucri 8 mm. alti gradati phyllaria linear-lanceolata longe acuminata; radii ca. 19; achenia compressa 10–costata hispidula; pappi straminei setae ca. 20 subequales achenio duplo longiores.

Plants 20–30 cm. high, the stems erectish or ascending, scattered on slender running rootstocks, often short, only 4–10 cm. high, terminated by a single head and continued by 2 or 3 branches from near the apex, these branches sometimes similarly terminated and prolonged; pubescence of short hairs about 0.5 mm. long, tipped with dark glands, and of long white hairs about 2 mm. long, all wide-spreading; leaves 2.5–3.5 cm. long, 4–10 mm. wide, obtuse, apiculate, narrowed to the rounded scarcely or not clasping base, erectish, pubescent like the stem and ciliate, entire or with one or two small blunt or acute teeth on each side, 1-nerved and sometimes with an obscure pair of lateral nerves; peduncles monocephalous, naked, 4–8 cm. long, very slender, pubescent like the stem; heads about 1.5 cm. wide; disk equaling involucre, this turbinate-hemispheric, 4–5-seriate, not strongly graduate, reflexed in age, the

outer phyllaries with herbaceous center and narrow scarious margin, the inner mainly subscarious, with narrow green midline; rays yellow, fertile, in age purplish outside, pilose toward tip of tube and on back of limb below, the tube 3 mm. long, the lamina nearly linear, 3-denticulate, 3–4-nerved, 6.5 mm. long, 1.3 mm. wide; disk flowers about 50, fertile, yellow, their corollas glabrous except for a few short hairs on the teeth, 4.5 mm. long (tube 1.8 mm., throat slender-funnelform, 2 mm., teeth ovate, 0.7 mm. long); achenes of ray and disk similar, obovate-oblong, somewhat compressed, 1.5 mm. long, rather sparsely hispidulous; pappus 1-seriate, 4.5–5 mm. long, of stiffish essentially equal finely hispidulous bristles; anthers subentire at base, with short linear-subulate terminal appendages; style branches 0.8 mm. long, the oblong stigmatic region 0.5 mm. long, the narrowly triangular acuminate hispidulous appendages 0.3 mm. long.

MEXICO: Above La Vegonia near San José, Tamaulipas, alt. 1000 m., 3 July 1930, *Bartlett* 10046 (type in herb. Univ. Michigan).

That plant is perplexingly intermediate between *Aplopappus* and *Chrysopsis*. In appearance and practically all features except the pappus it agrees with *Chrysopsis*, particularly with *C. pilosa* Nutt. The strictly 1-seriate pappus, however, makes it necessary to refer it to *Aplopappus*, where the only section that can receive it is *Isopappus*. The two species referred to that section in the late Dr. H. M. Hall's monograph of "Haplopappus" are both annuals and too different from *A. bartlettii* to require detailed comparison. *Chrysopsis pilosa*, although very similar in general appearance, is an annual and has a strongly differentiated outer pappus, broadly obovoid achenes, and various other distinctive characters.

**Wedelia adhaerens** Blake, sp. nov.

Herba verisim. erecta dichotome ramosa; caulis dense hamato-hispidulus sparsissime hispidus; folia remota ovalia vel ovali-ovata acuta basi late rotundata inconspicue serrulata triplinervia chartacea aspere pubescentia; capitula parva radiata aurea apice caulis et ramorum ternata sublonge pedunculata; involucri ca. 3-seriati subaequalis ca. 7.5 mm. longi phyllaria ovato-lanceolata acuminata hispido-strigosa et strigillosa supra medium herbacea suberecta; pappus cyathiformis longe stipitatus.

Apparently herbaceous, 0.5 m. high and more; stem slender, 2.5 mm. thick, densely hispidulous with short mostly spreading hamate hairs and especially below sparsely hispid with ascending hairs; leaves opposite; petioles 1.2 mm. long, hamate-hispidulous and rather densely hispid; blades of larger leaves 3–3.5 cm. long, 1.5–2.5 cm. wide, remotely and obscurely callous-serrulate with 4–6 teeth on each side, above dull green, densely and evenly hamate-hispidulous with spreading hairs, sparsely tuberculate-hispid with antrorse-curved hairs, beneath scarcely lighter green but slightly shining, densely hamate-hispidulous on surface, on veins and veinlets sparsely antrorse-hispid, triplinerved from near base and loosely prominulous-reticulate beneath; upper leaves and those of branches smaller but otherwise similar, 1–2.3 cm. long, 8–13 mm. wide; heads 1.5 cm. wide, usually in clusters of 3 at tips of stem and branches, the peduncles slender, usually naked, pubescent like the stem, the terminal one about 1 cm. long, the lateral at maturity 2.5–5 cm. long, sometimes bearing a bract and a secondary head; involucre campanulate, 7.5–9.5 mm. high, about 3-seriate, subequal or slightly graduate, the two outer series of phyllaries lanceolate to lance-ovate, 1.3–3 mm. wide, densely hispidulous and less densely tuberculate-hispid with ascending hairs, indurated

and whitish about to middle, the acuminate or acute callous-pointed herbaceous tip loosely erectish, pubescent on both faces, the inmost series shorter and without herbaceous tip; disk 6–7 mm. high, about 4 mm. thick; rays about 6, yellow, pistillate, the tube 2 mm. long, essentially glabrous, the lamina oval, 3-denticulate, up to 9 mm. long, 5.5 mm. wide, about 13-nerved, hispidulous and gland-dotted dorsally; disk flowers about 12, their corollas yellow, essentially glabrous except on the hispidulous teeth, 5 mm. long (tube 2 mm., throat slender-funnelform, 2.5 mm., teeth broadly ovate, 0.5 mm.); pales scarious, sometimes purplish, acute or obtusish, sometimes shortly 3-lobed, hispidulous-ciliolate on margin and keel above; ray achenes obcompressed, plumpish, obovate, subalate-margined, 1-ribbed on inner face, mottled, glabrous except at the slightly hispidulous apex, truncate or emarginate at apex, 2-calloused at base, 4–4.2 mm. long, 2.3–2.5 mm. wide, their pappus a ciliolate cup 0.4 mm. high, borne on a usually slender stipe 0.5–0.8 mm. long, the whole 1–1.2 mm. long, readily detergible at maturity; mature disk achenes not seen, their pappus (young stage) a lacerate cup 0.7 mm. high, connate with 2 awns 1–1.3 mm. long.

GUATEMALA: In logwood swamp, Dos Arroyos, Dept. Petén, 15 March 1931, *Bartlett* 12111 (type no. 1,540,626, U. S. Nat. Herb.).

Nearest *Wedelia parviceps* Blake, and essentially indistinguishable as to heads and involucre, except for their slightly larger size. In that species, however, the leaves are ovate to lanceolate, not half as wide as long, the achene is only about two-thirds as long, and its subsessile or short-stipitate pappus-cup, including its stipe, is only half as long.

**Melanthera parviceps** Blake, sp. nov.

Herba opposite ramosa; caulis quadrangularis breviter strigosus; folia oblongo-triangularia vel lanceolata acuminata basi cuneata crenato-serrata tenuia utrinque viridia hispidula et hispido-hirsuta, minoribus saepius leviter hastatis; capitula parva anthesi 3–6 mm. diam. apice caulis ramorumque irregulariter cymosa-paniculata, pedunculis saepe 2–4-cephalis; involucri ca. 3 mm. alti phyllaria ovata acutiuscula strigosa et ciliata apice breviter herbacea; paleae receptaculi brevissime acutatae.

"Fragile herb, 2 m. high, spearmint-scented;" stem bluntly 4-angled, up to 4 mm. thick, purplish, rather sparsely short-strigose; principal internodes 1–1.5 dm. long; leaves opposite; petioles slender, hispid-hirsute, 1–4 cm. long, the larger narrowly cuneate-winged at apex for about 1 cm. (passing into the blade); blades of larger leaves triangular-oblong, about 14 cm. long, 4–4.5 cm. wide, short-cuneate at base, crenate-serrate nearly throughout with about 35 pairs of subequal rounded apiculate teeth about 1 mm. high and about 3 mm. apart, triplinerved, lightly prominulous-reticulate beneath, above dark green, evenly but not densely hispidulous and hispid-hirsute, beneath scarcely lighter green, hispidulous on surface, hispid-hirsute on veins and veinlets; smaller leaves usually slightly hastate at base, more sharply toothed, 7 cm. long and 3 cm. wide, or smaller; heads usually in 2's–4's at apex of stem and branches, in fruit 5 mm. high, 6–8 mm. thick, the peduncles strigose, 1–4-headed, mostly 1–5 cm. long, the pedicels usually 0.5–2.5 cm. long; involucre 2-seriate, subequal, 3–3.5 mm. high, appressed, the phyllaries ovate, acutish, callous-tipped, strigose, ciliate above; disk in flower about 4 mm. high, 6 mm. thick; flowers about 24, their corollas white, hispidulous on teeth, 3.2 mm. long (tube 0.7 mm., throat campanulate, 1.5 mm., teeth triangular-ovate, 1 mm. long); pales hispidulous and sometimes purplish above, shortly and rather bluntly pointed, 4.2 mm. long (the narrowed tip 0.8

mm. long); achenes plump, lenticular, hispidulous on apex, 2.2 mm. long; pappus caducous, of 3–4 (or more?) subequal slender hispidulous awns 1.5 mm. long or less.

BRITISH HONDURAS: In ravine, Little Mountain Pine Ridge, El Cayo District, 1 March 1931, *Bartlett* 11882 (type no. 1,540,623, U. S. Nat. Herb.).

Related to *Melanthera purpurascens* Blake, of Chiapas, but a much larger, coarser, erect plant, with even smaller heads, usually grouped at tips of branches, and less pointed pales.

**Calea fluviatilis** Blake, sp. nov.

Fruticulus pedalis; caules tenues ramulosi foliosi minute hispiduli glabrescentes; folia angustissime lineari-lanceolata ca. 2.5 cm. longa 1.5 mm. lata coriacea remote calloso-serrulata subglabra glanduloso-adspersa; capitula discoidea parva 13-flora 3–7 terminalia cymosa, in pedunculis ca. 1 cm. longis; involucri 4–5 mm. alti phyllaria exteriora pauca triangularia supra medium vel maxima ex parte herbacea glanduloso-adspersa interioribus ovalibus vel ovatis subscariosis apice saepe purpurascentibus subglabris aequalia vel breviora; pappi paleae 20 acheniis hispidulis subduplo longiores.

Undershrub 25 cm. high, several-stemmed from a thick woody flattened caudex 2.5 cm. wide; stems erectish, somewhat trichotomously branched, in age with numerous small branchlets, subterete or subangulate, minutely hispidulous on the younger parts with erectish hairs, glabrescent; leaves opposite; petioles 1 mm. long; blades 1.3–2.8 cm. long, 1–2 mm. wide, acuminate to each end, obtusely callous-tipped, remotely 2–3-denticulate or serrulate on each side with low callous teeth, triplinerved, somewhat revolute-margined, deep green, dotted on both sides with sessile shining yellowish glands, otherwise glabrous or sparsely and obscurely strigillose beneath; heads about 7 mm. high, 4 mm. thick, in terminal clusters of 3–7, the peduncles very slender, 8–12 mm. long, hispidulous and glandular-dotted; involucre 3–4-seriate, more or less distinctly graduate, the outermost phyllaries triangular, obtusely callous-tipped, 3–5 mm. long, 0.7–1 mm. wide, appressed, coriaceous-herbaceous above middle or nearly throughout, 1-ribbed and with an obscure pair of nerves, dotted with sessile glands, the others yellowish-brown, usually purplish-tipped, rounded, several-vittate; corollas yellow, glabrous, somewhat zygomorphic, 4.8 mm. long (tube 2.2 mm., throat 1–1.2 mm., teeth unequal, 1.2–1.8 mm. long, 2 or 3 being less deeply cleft than the others); pales oblong, 5 mm. long, obtuse, sometimes abruptly and obtusely short-pointed, glabrous, yellowish, about 3-vittate; achenes blackish, erectish-hirsutulous except toward base, 2 mm. long; pappus paleae about 20, narrowly linear-lanceolate, acuminate, subequal, hispidulous-ciliolate, 3.5 mm. long.

BRITISH HONDURAS: On stones in Río Privación, Mountain Pine Ridge, El Cayo District, 26 Feb. 1931, *Bartlett* 11790 (type no. 1,540,622, U. S. Nat. Herb.).

A member of the subgenus *Eucalea*, very distinct from any other North American species in foliar characters.

**Liabum dimidium** Blake, sp. nov.

Frutex scandens; caulis sordide arachnoideo-tomentosus glabrescens et praecipue supra pilosus vel pilosulus pilis sordidis patentibus multiloculatis; folia late ovata petiolata serrulato-denticulata triplinervia supra tenuiter arachnoidea glabrata subtus albido-tomentosa; capitula 7–11-flora discoidea numerosissima, paniculam latam efformantia; involucri ca. 4-seriati 5–6 mm.

alti pappo subduplo brevioris phyllaria ovata ad oblongo-linearia obtusa vel rotundata ciliata; achenia dense hispidula; pappus albidus 6.5 mm. longus duplex, exteriore setuloso ca. 1.5 mm. longo.

"Lax scrambling shrub, 6 m. high;" stem (above) subterete, striatulate, 6 mm. thick, rather thinly arachnoid-tomentose, glabrescent, sordid-pilose or -pilosulous especially in inflorescence; leaves opposite; petioles slender, 1.3–3 cm. long, thinly arachnoid, glabrescent; blades of larger leaves 9–12 cm. long, 6–9.5 cm. wide, relatively thin, acute, at base broadly cuneate or rounded-cuneate, serrulate-denticulate above the mainly entire base with very slender teeth about 0.6 mm. long and 3–6 mm. apart, beneath compactly but not thickly dull-whitish-tomentose; panicles terminating stem and upper branches, together forming a loose pyramidal panicle about 28 cm. wide and 20–30 cm. long, thinly arachnoid and rather densely sordid-pilosulous with many-celled spreading hairs, the heads partly sessile, partly on pedicels up to 4 mm. long; involucre 4–5-seriate, strongly graduate, the 2–3 outer series of phyllaries ovate, somewhat fleshy, striate when dry, dull green, obtuse, ciliate and sparsely sordid-pilosulous, the 2 inner series linear-oblong, about 1 mm. wide, thinner, not striate, sordid-ciliate, erect; receptacle shallowly alveolate, the edges of the alveolae minutely hispidulous; corollas yellow, pilosulous on upper part of tube, 8 mm. long (tube slender-funnelform, 3.3 mm. long, throat thick-cylindric, 2 mm. long, teeth linear-triangular, 2.7 mm. long, hispidulous at apex); achenes (not truly mature ?) 1.3 mm. long; pappus yellowish-white, double, the outer setulose, about 1.5 mm. long, scarcely wider than the inner, the inner of hispidulous bristles bent at apex, 7 mm. long.

GUATEMALA: Tikal, Dept. Petén, 12–15 April 1931, *Bartlett* 12602 (type no. 1,540,627, U. S. Nat. Herb.)

A member of the group separated by Rydberg under the generic name *Sinclairia* Hook. & Arn., and related to *Liabum polyanthum* Klatt and **Liabum brachypus** (Rydb.) Blake.[2] The former has a longer involucre (about 7–9 mm. high), nearly or quite equaling the pappus, and the inner phyllaries are strongly spreading or reflexed above at maturity. *Sinclairia pittieri* Rydb., the type of which I have studied, is not separable by any real character from *L. polyanthum*. *Liabum brachypus* lacks the sordid spreading hairs of the new species, and has a somewhat longer involucre (about 7 mm.) and a dense inflorescence. The specific name of the new species refers to the relative length of the involucre and the fruiting head.

[2] *Sinclairia brachypus* Rydb. N. Amer. Fl. **34**: 299. 1927.

ZOOLOGY.—*Two new pocket mice from Arizona.*[1] E. A. GOLDMAN, Biological Survey.

When *Perognathus amplus* was described by Osgood in his revision of the genus (North Amer. Fauna, No. 18, p. 32, Sept. 20, 1900) the type was unique. Some subsequent efforts to obtain topotypes have been unsuccessful, owing perhaps to seasonal or cyclic variations in numbers. Over thirty specimens from various localities in the general region are, however, regarded as fairly representative. A series from

[1] Received June 16, 1932.

the low, open, desert region of southwestern Arizona presents the decidedly paler coloration characterizing some of the other mammals of that area. Specimens from northwestern Arizona, south of the Grand Canyon, also exhibit a departure from the typical form. The new geographic races are differentiated as follows:

**Perognathus amplus rotundus,** subsp. nov.

Gila Pocket Mouse

*Type.*—From Wellton, Yuma County, Arizona. No. 250470, ♂ adult, U. S. National Museum (Biological Survey collection), collected by Bernard Bailey, November 9, 1931. Original No. A4353; X catalogue No. 27029.

*Distribution.*—Desert region of southwestern Arizona, and probably adjoining parts of Sonora.

*General characters.*—A large, light-colored subspecies, closely allied to *Perognathus amplus amplus*, of central Arizona, but ground color of upper parts a decidedly paler shade of pinkish buff, less obscured by black on face and along flanks; postauricular spots rather prominent; cranial characters also distinctive.

*Color.—Type*: Upper parts near pale pinkish buff (Ridgway, 1912), purest on upper surface of muzzle, sides of head, shoulders, flanks and outer surfaces of thighs, the top of head and back finely lined with black; under parts, forelimbs and hind feet white; ears pinkish buff externally, except anterior fold which is dusky, thinly clothed internally with blackish hairs, and distinctly edged with white at posterior base; small dusky areas at base of vibrissae on sides of muzzle (not continued in a narrow line across face as in typical *amplus*); tail thinly haired, slightly crested and tufted terminally, grayish above, whitish below, becoming dusky at tip.

*Skull.*—Very similar in general to that of *P. a. amplus*, but more robust; rostrum and nasals distinctly broader; mastoids broader anteriorly, bulging upward more prominently along outer border of parietal, but narrower, less inflated posteriorly; dentition about as in *amplus*.

*Measurements.—Type*: Total length, 170 mm.; tail vertebrae, 90; hind foot, 21. Average of five adult topotypes: 161 (155–165); 86 (82–95); 20.4 (20–21). *Skull* (type): Occipitonasal length, 24.2; greatest breadth (across audital bullae at meatus), 15.2; zygomatic breadth (posteriorly), 13.3; interorbital breadth, 5; length of nasals, 9.3; width of nasals (in front of incisors), 2.5; interparietal, 3.2 x 3.4; maxillary toothrow (alveoli), 3.6.

*Remarks.*—The pallid general coloration and most notably the lighter head of *Perognathus amplus rotundus* readily distinguishes it externally from *P. a. amplus*, and the skull differs markedly from that of the type of the latter. Intergradation may, however, be assumed.

*Specimens examined.*—Ten, all from the type locality.

**Perognathus amplus pergracilis,** subsp. nov.

Hualpai Pocket Mouse

*Type.*—From Hackberry, Mohave County, Arizona (altitude 3500 feet). No. 227528, ♂ young adult, U. S. National Museum (Biological Survey collection), collected by E. A. Goldman, September 14, 1917. Original number 23304.

*Distribution.*—Desert region of northwestern Arizona, south of the Grand Canyon.

*General characters.*—Similar to *P. a. amplus*, but of more slender proportions; ground color of upper parts paler pinkish buff. Differing from *P. a. rotundus* in slenderness, and darker general tone of upper parts due to density of overlying black-tipped hairs, especially on head.

*Color.—Type*: Ground color of upper parts pale pinkish buff, purest along lateral line from cheeks to thighs, the head and back moderately and uniformly overlaid with black; under parts, forelimbs and hind feet white; ears pinkish buff externally, except anterior fold which is dusky, thinly clothed internally with blackish hairs; tail grayish or light brownish above, becoming darker toward tip, whitish below to small terminal tuft which is dusky all around.

*Skull.*—Similar to those of *P. a. amplus* and *P. a. rotundus*, but smaller and relatively narrower in greater dimensions; mastoids and audital bullae relatively smaller and much less inflated, the mastoids less rounded and produced posteriorly beyond plane of occiput; interorbital region actually as well as relatively broader.

*Measurements.—Type*: Total length, 143 mm.; tail vertebrae, 80; hind foot, 21. Average of three adults from Little Meadows (west of Kingman, Arizona): 154 (151–156); 86 (80–90); 21.5 (21–22). *Skull* (type): Occipitonasal length, 22; greatest breadth (across audital bullae at meatus), 12.8; zygomatic breadth (posteriorly), 11.7; interorbital breadth, 5.4; length of nasals, 8.5; width of nasals (in front of incisors), 2.2; interparietal, 2.8 x 3.9; maxillary toothrow (alveoli), 3.5.

*Remarks.—Perognathus amplus pergracilis* combines the pale buffy ground color of *P. a. rotundus* with the more obscured head and dorsum of *P. a. amplus*, due to overlying dusky hairs, and it differs notably from both in slenderer proportions.

*Specimens examined.*—Total number, 16, all from Arizona as follows: Beal Spring (2 miles from Kingman), 3; Big Sandy Creek, 1; Hackberry (type locality), 5; Little Meadows (west of Kingman), 3; Peach Springs, Hualpai Indian Reservation, 3; Signal, 1.

## SCIENTIFIC NOTES AND NEWS

The honorary degree of doctor of science was conferred on Dr. D. J. McAdam, Jr., of the Bureau of Standards at the commencement exercises of Washington and Jefferson College on June 4, 1932.

## Obituary

Dr. Louis W. Austin, international authority on radio transmission, and member of the staff of the Bureau of Standards, died in Washington on June 27 at the age of 64.

Dr. Austin received the degree of doctor of philosophy at the University of Strasburg (Germany) in 1893. He served as professor of physics at the University of Wisconsin and at the Reichsanstalt in Berlin. In 1904 he came to the Bureau of Standards and began researches in wireless telegraphy. From 1908 to 1923 he served as head of the Naval Research Laboratory, returning to the Bureau of Standards in 1923.

Dr. Austin was a member of the American Physical Society, Washington Academy of Sciences, Philosophical Society of Washington, American Institute of Radio Engineers and other scientific organizations. He received the medal of the American Institute of Radio Engineers in 1927.

Dr. Austin's researches on radio transmission received wide recognition and he had only recently been elected to the presidency of the International Scientific Radio Union.